

## In the Specification

Please cancel the present section of the specification headed "DETAILED DESCRIPTION OF AN EXEMPLARY EMBODIMENT" which extends from page 4, line 9, to page 9, the bottom line, and substitute the following replacement section (in accordance with the Revised Notice "Amendments May Now Be Submitted in Revised Format" of 02/13/03):

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### --DETAILED DESCRIPTION

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FIG. 1 illustrates the model of a typical Quad Flat Pack (QFP) integrated circuit device. The Quad Flat Pack may comprise a 1.0 inch square integrated circuit device package 10. The integrated circuit (IC) 12 itself may only comprise a 0.2 inch square or 0.3 inch square wafer of silicon containing the actual integrated circuitry of the integrated circuit package 10. The device package 10 is formed by encapsulating the integrated circuit 12 in a plastic medium 14 which defines the physical dimensions of the device package 10. The plastic medium 14 protects and supports the integrated circuit 12 and contains the lead frame conductors which electrically connect the IC 12 to the external input/output (I/O) pins 18 of the device package 10. The lead frame conductors 16 connect to the IC 12 via bonding wires 20 which directly connect to strategic circuitry nodes on the IC 12.

FIG. 2 illustrates the electrical model of the typical integrated circuit package of FIG. 1. FIG. 2 illustrates how the conductor-leads lead frame conductors 16 from the I/O pins 18 to the integrated circuit 12 are not ideal transmission lines but in practice exhibit a per length series inductance.

Longer lengths of the conductor leads lead frame conductors 16 result in larger values of the inherent series inductance. Input leads of the lead frame conductors 16 connect the I/O input pins 18<sub>IN</sub> of the I/O pins 18 to input buffers 22 on the integrated circuit 12, and output leads of the lead frame conductors 16 connect the output pin 18<sub>OUT</sub> of the I/O pins 18 to output buffers such as 24 on the integrated circuit 12. In general, the input and output conductor leads of the lead frame conductors 16 exhibit input series inductance  $L_{IN}$  and output series inductance  $L_{OUT}$ .

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Ideally, the inductance of the  $V_{CC}$  and  $V_{GND}$  leads would be zero henries. In a preferred embodiment of the present invention the effective inductance of the  $V_{CC}$  and  $V_{GND}$  leads rails is effectively reduced with multiple parallel branches since there are typically multiple  $V_{CC}$  and  $V_{GND}$  pins in a given integrated circuit device package 10. Utilization of multiple signal paths to reduce the effective inductance of a data signal path provided by a lead frame conductor 16 is not feasible; therefore the effective series inductances  $L_{IN}$  and  $L_{OUT}$  of the lead frame conductors 16 preferably exhibit a small amount of "lossy" inductance. By making the series inductance of lead frame conductors the conductor leads 16 lossy, the detrimental EMI effects of the series inductances may be thereby reduced.

Given the construction of the lead frame which provides the lead frame conductors 16, the packaging function for the integrated circuit 12 is preferably completed by placing the lead frame 16 with bonded integrated circuit 12 into a injection molding cavity where molten plastic is injected to

encapsulate the lead frame 16 and integrated circuit 12 to form the device package 10. The plastic material 14 is preferably electrically passive and electrically non-conducting so that it will cause no degradation of the electrical signals to and from the integrated circuit 12.

In a preferred embodiment of the present invention a modeled plastic material 14 having desired electromagnetic properties to advantageously affect the signals to and from the integrated circuit 12 as the signals are routed through the lead frame 16 of the device is utilized. A small amount of ferrite powder is preferably blended with the plastic material 14 to achieve the slightly lossy magnetic characteristic of the encapsulating plastic medium 14 surrounding the lead frame conductors 16. Ferrite is preferred because of its high resistivity and permeability.

FIG. 3 illustrates the effects of the introduction of ferrite powder into the encapsulating plastic of the integrated circuit device package of FIG. 1. The introduction of a ferrite material into the encapsulating plastic 14 alters the permeance of the encapsulating medium 14 and thereby affects the electrical characteristics of the inherent series impedance of the lead frame conductors 16. The ferrite material in the encapsulating medium 14 causes the series inductance of the lead frame conductors 16A and 16B to behave as a lossy inductor  $L_F$ . Further, the ferrite material contributes to the mutual inductance  $M_F$  and resulting coupling primarily associated with adjacent lead frame conductors leads 16A and 16B. The ferrite material exhibits hysteresis loss, but because ferrite has high characteristic resistivity, it exhibits no eddy-

current loss. Increasing the permeance of the physical medium 14 surrounding the inductance with the presence of a magnetic material such as ferrite produces an effect opposite to the effect resulting with magnetic core inductors; instead of concentrating the magnetic flux within the center of the inductor to thereby augment the effective inductance as with a magnetic core, the increased permeance of the surrounding medium 14 due to the magnetic material tends to distribute the flux throughout the medium away from the inductor thereby attenuating the effective inductance.

FIG. 4 illustrates the resulting preferred characteristic signal shape of a given data signal when a ferrite material is introduced into the encapsulating medium. The lossy inductor  $L_F$  as shown in FIG. 3 would serve to attenuate only the highest frequency signal components while introducing generally little true inductance effects of overshoot and ringing associated with the series inductance of the leads lead frame conductors 16 when no ferrite is present. The Q of the inherent series inductance of the conductor leads lead frame conductors 16 is thereby minimized rather than maximized. Thus, the intentionally introduced inductor loss reduces the undesired effects of the inherent series inductance such as overshoot and ringing.

FIG. 5 illustrates a two conductor mutual coupling model of the present invention. Introduction of mutual coupling and signal crosstalk between two adjacent lead frame conductors 16A and 16B would be an undesirable effect that is preferably minimized. Current flowing into conductor 16A introduces magnetic flux 32 through adjacent conductor 16B thereby inducing a current

therein. In a preferred embodiment of the present invention a relatively small amount of ferrite material is blended in the encapsulating plastic 14 resulting in a relative permeability of the surrounding material 14 that is not too high to cause significant mutual coupling but yet sufficient to desirably affect the series inductance of the lead conductors 16. In a preferred embodiment of the present invention, the relative permittivity of the encapsulating medium 14 ranges from 5 to 10.

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Regarding the two conductor mutual coupling example as shown in FIG. 3, the actual amount of mutual inductance  $M_F$  between two adjacent lead frame conductors 16A and 16B is small with respect to the self-inductance  $L_F$  of each conductor 16. In a preferred embodiment of the present invention, the reduction of crosstalk on any particular lead frame conductor 16 may be further achieved by placing that particular lead frame conductor 16 adjacent to a  $V_{CC}$  or  $V_{GND}$  lead to avoid any coupling to another data signal path.

FIG. 6 illustrates a preferred embodiment of the present invention in which mutual coupling between adjacent leads is eliminated. The virtual elimination of the mutual inductance may be achieved by molding the device package 10 in two steps. The first step preferably comprises constructing the lead frame which provides lead frame conductors 16 and then forming or molding individual ferrite "microbeads" 30 on each lead frame conductor 16. The microbeads 30 are preferably offset so they do not interfere with adjacent microbeads 30. The microbead 30 are electrically isolated from the adjacent lead frame conductors 16.

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In a preferred embodiment of the present invention the microbeads 30 are made of pure ferrite material which may be constructed using known ceramic techniques, and the microbeads 30 would be formed as an integral part of the lead frame 16. The microbeads 30 are utilized in a manner analogous to the utilization of ferrite bead chokes in radiofrequency transmission lines and antennas. The bead surrounds the transmission line and effectively chokes undesired high frequency signals immediately external to the transmission line that are the source of electromagnetic interference without affecting data signals passing therethrough.

The second step preferably comprises ordinary plastic encapsulation of the lead frame that provides lead frame conductors 16 and the integrated circuit 12 upon completion of the bonding and wiring of the IC 12 to the lead frame 16. In an alternative embodiment of the present invention the inclusion of a ferrite microbead 30 on any given lead frame conductor lead 16 is optional depending upon the type of signal transmitted thereon. For example, V<sub>CC</sub> and V<sub>GND</sub> signals perform better if there is no ferrite bead 30 on those leads. In a preferred embodiment, the standard lead frame 16 is constructed with a microbead 30 on each lead frame conductor lead 16. Microbeads 16 may be selectively removed by crushing away the undesired beads 30 which is facilitated by the inherent brittleness of ferrite. Preferably, a simple press may be utilized having small crushing pins arranged above the corresponding microbeads to be crushed in which all undesired microbeads 30 may be removed in a single step.

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FIG. 7 illustrates a preferred embodiment of the present invention in which the magnetic flux is contained within the ferrite beads. The ferrite bead 30 surrounding conductor lead 16A completely contains the magnetic flux 32 generated by the current flowing into conductor lead 16A. Thus, no current is induced in conductor lead 16B from the magnetic flux 32 created by the current flowing through conductor lead 16A. In a preferred embodiment of the present invention, only the microbeads 30 contain ferrite wherein the encapsulating medium 14 entirely comprises nonmagnetic plastic. Alternatively, a small amount of ferrite may be blended in with the encapsulating plastic 14 in conjunction with the utilization of ferrite beads to further achieve the reduction of electromagnetic interference.

FIG. 8 illustrates the preferred placement of the ferrite beads of the present invention relative to the integrated circuit wafer in the device package. The most effective physical location for the microbeads 30 is as near to the integrated circuit 12 as possible. With the required close spacing of the lead frame conductors 16 near the IC bonding pads 20, the physical size of a microbead 30 may not be very large, however the effects of the reduced size are offset by the fact that the placement of the ferrite microbead 30 near the IC 12 is nearly ideal.

FIG. 9 illustrates the resulting electrical circuit model of a given conductor path in an integrated circuit device package of the present invention. An output signal  $V_{OUT}$  from the integrated circuit 12 feeds into an output buffer 24 which is externally connected through an IC bonding wire pad

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20. The bonding wire 20 exhibits a small series inductance  $L_B$  which is small relative to the inductance  $L_F$  of the ferrite microbead 30. The lead frame conductor 16 exhibits a characteristic lumped series inductance  $L_{OUT}$  and shunt capacitance  $C_{OUT}$ , the effects of which are negligible compared to the inductance  $L_F$  of the microbead 30, and extends through the encapsulating medium 14. The effects of inductance  $L_{OUT}$  and capacitance  $C_{OUT}$  may be further reduced by the blending of ferrite with the encapsulation material 14. The lead frame conductor 16 connects to an external pin  $18_{OUT}$  18 on the exterior of the device package 10.

In view of the above detailed description of a preferred embodiment and modifications thereof, various other modifications will now become apparent to those skilled in the art. The contemplation of the invention below encompasses the disclosed embodiments and all reasonable modifications and variations without departing from the spirit and scope of the invention.--